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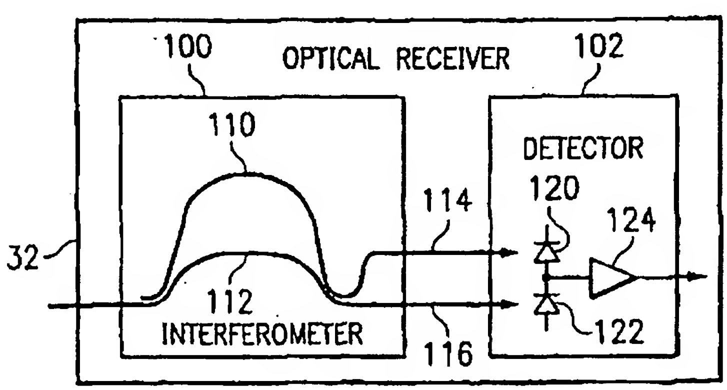
(54) Title: RECEIVER AND METHOD OF RECEIVING A MULTICHANNEL OPTICAL SIGNAL



(57) Abstract: A method and system for transmitting information in a wavelength division multiplex (WDM) or other suitable multichannel optical communication system includes receiving a multichannel signal having a symbol rate and comprising a plurality of non-intensity modulated optical information signals. The non-intensity modulated optical information signals have a minimum channel spacing comprising a multiple of the symbol rate within 0.4 to 0.6 of an integer. The non-intensity modulated optical information signals are separated from the multichannel signal and each converted into an intensity modulated optical information signal using an asymmetric interferometer. A data signal is recovered from the intensity modulated optical information signal.

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information channel in accordance with one embodiment of the present invention; and

FIGURE 15 is a block diagram illustrating an optical receiver for extracting a clock signal from a multimodulated signal in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates an optical communication system 10 in accordance with one embodiment of the present invention. In this embodiment, the optical communication system 10 is a wavelength division multiplexed (WDM) system in which a number of optical channels are carried over a common path at disparate wavelengths. It will be understood that the optical communication system 10 may comprise other suitable single channel, multichannel or bi-directional transmission systems.

Referring to FIGURE 1, the WDM system 10 includes a WDM transmitter 12 at a source end point and a WDM receiver 14 at a destination end point coupled together by an optical link 16. The WDM transmitter 12 transmits data in a plurality of optical signals, or channels, over the optical link 16 to the remotely located WDM receiver 14. Spacing between the channels is selected to avoid or minimize cross talk between adjacent channels. In one embodiment, as described in more detail below, minimum channel spacing (df) comprises a multiple of the transmission symbol and/or bit rate (B) within 0.4 to 0.6 of an integer (N). Expressed mathematically: $(N+0.4)B<df<(N+0.6)B$. This suppresses neighboring channel cross talk. It will be understood that channel spacing may be suitably varied without departing from the scope of the present invention.

information signal may comprise intensity modulation of a non-data signal.

In a particular embodiment, as described in more detail below, the WDM signal 26 comprises phase or frequency modulated optical information signals 24 which are amplified using the bi-directional DRAs 44 with no cross talk between the channels 24 due to XGM. In this embodiment, the bi-directional DRAs 44 provide amplification at a superior optical signal-to-noise ratio and thus enable longer transmission distances and improved transmission performance.

FIGURE 2 illustrates details of the optical sender 20 in accordance with one embodiment of the present invention. In this embodiment, the optical sender 20 comprises a laser 70, a modulator 72 and a data signal 74. The laser 70 generates a carrier signal at a prescribed frequency with good wavelength control. Typically, the wavelengths emitted by the laser 70 are selected to be within the 1500 nanometer (nm) range, the range at which the minimum signal attenuation occurs for silica-based optical fibers. More particularly, the wavelengths are generally selected to be in the range from 1310 to 1650 nm but may be suitably varied.

The modulator 72 modulates the carrier signal with the data signal 74 to generate the optical information signal 24. The modulator 72 may employ amplitude modulation, frequency modulation, phase modulation, intensity modulation, amplitude-shift keying, frequency-shift keying, phase-shift keying and other suitable techniques for encoding the data signal 74 onto the carrier signal. In addition, it will be understood that different modulators 72 may employ more than one modulation system in combination.

frequency modulated onto the carrier signal and then remodulated with intensity modulation synchronized with the signal clock to provide superior power tolerance in the transmission system.

Referring to FIGURE 4, the optical sender 80 includes a laser 82, a non-intensity modulator 84 and data signal 86. The non-intensity modulator 84 modulates the phase or frequency of the carrier signal from the laser 82 with the data signal 86. The resulting data modulated signal is passed to the intensity modulator 88 for remodulation with the clock frequency 90 to generate a dual or otherwise multimodulated optical information signal 92. Because the intensity modulation based on the clock is a non-random, completely periodic pattern, little or no cross talk due to XGM is generated by the DRAs 44 so long as there is a slight velocity mismatch in the forward pumping direction. FIGURE 5 illustrates the waveform of the dual modulated optical information signal 92.

FIGURE 6 illustrates details of the optical receiver 32 in accordance with one embodiment of the present invention. In this embodiment, the optical receiver 32 receives a demultiplexed optical information signal 24 with the data modulated on the phase of the carrier signal with phase shift keying. It will be understood that the optical receiver 32 may be otherwise suitably configured to receive and detect data otherwise encoded in an optical information signal 24 without departing from the scope of the present invention.

Referring to FIGURE 6, the optical receiver 32 includes an asymmetric interferometer 100 and a detector 102. The interferometer 100 is an asymmetric Mach-Zender or other suitable interferometer operable to convert a

non-intensity modulated optical information signal 24 into an intensity modulated optical information signal for detection of data by the detector 102. Preferably, the Mach-Zender interferometer 100 with wavelength dependent loss and good rejection characteristics for the channel spacing.

The Mach-Zender interferometer 100 splits the received optical signal into two interferometer paths 110 and 112 of different lengths and then combines the two paths 110 and 112 interferometrically to generate two complimentary output signals 114 and 116. In particular, the optical path difference (L) is equal to the symbol rate (B) multiplied by the speed of light (c) and divided by the optical index of the paths (n). Expressed mathematically: $L=Bc/n$.

In a particular embodiment, the two path lengths 110 and 112 are sized based on the symbol, or bit rate to provide a one symbol period, or bit shift. In this embodiment, the Mach-Zender interferometer 100 has a wavelength dependent loss that increases the rejection of neighboring channels when channel spacing comprises the symbol transmission rate multiple within 0.4 to 0.6 of an integer as previously described.

The detector 102 is a dual or other suitable detector. In one embodiment, the dual detector 102 includes photodiodes 120 and 122 connected in series in a balanced configuration and a limiting amplifier 124. In this embodiment, the two complimentary optical outputs 114 and 116 from the Mach-Zender interferometer 100 are applied to the photodiodes 120 and 122 for conversion of the optical signal to an electrical signal. The limiting electronic amplifier 124 converts the electrical signal to a digital signal (0 or 1) depending on the optical

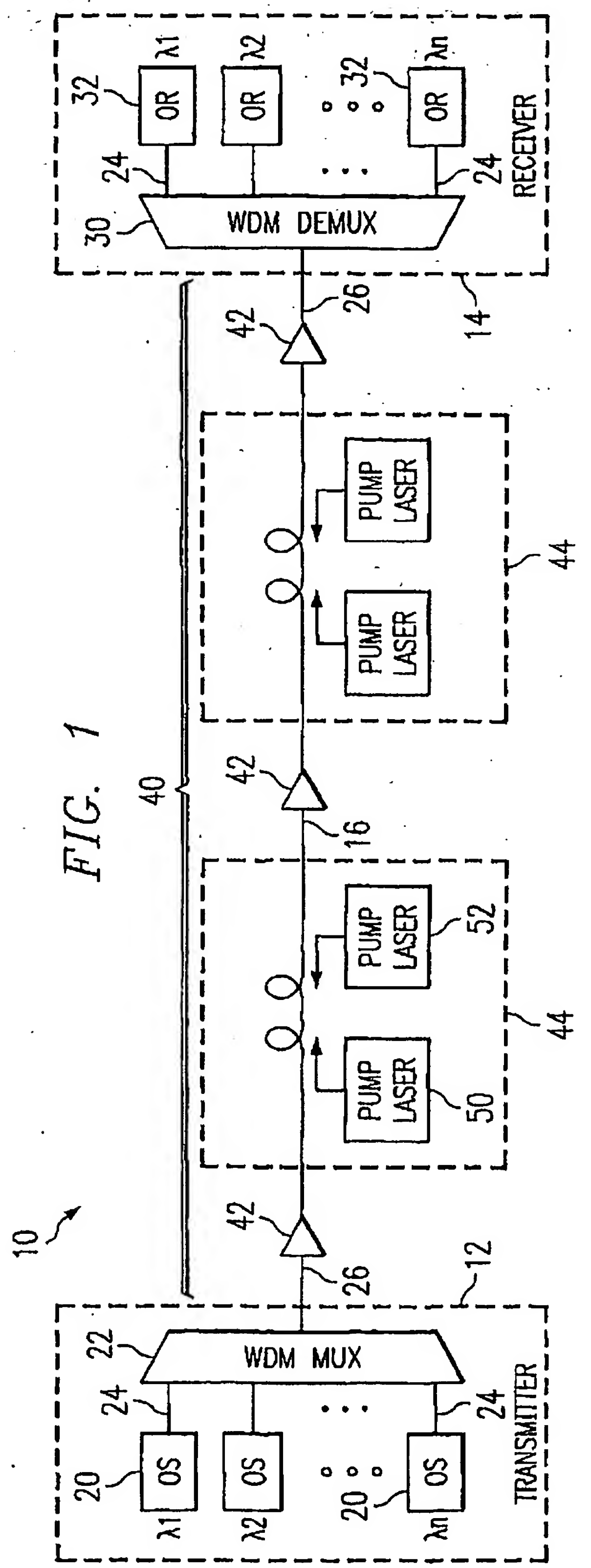

RECEIVER
WDM DEMUX
OR
λ1
λ2
λn
PUMP LASER
PUMP LASER
PUMP LASER
PUMP LASER
TRANSMITTER
WDM MUX
OS
10
12
14
16
20
22
24
26
30
32
40
42
44
50
52

FIG. 1

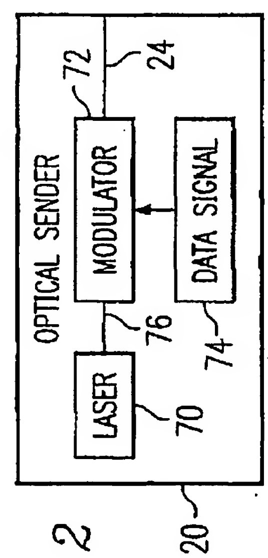

OPTICAL SENDER
LASER
MODULATOR
DATA SIGNAL
20
24
70
72
74
76

FIG. 2

FIG. 5

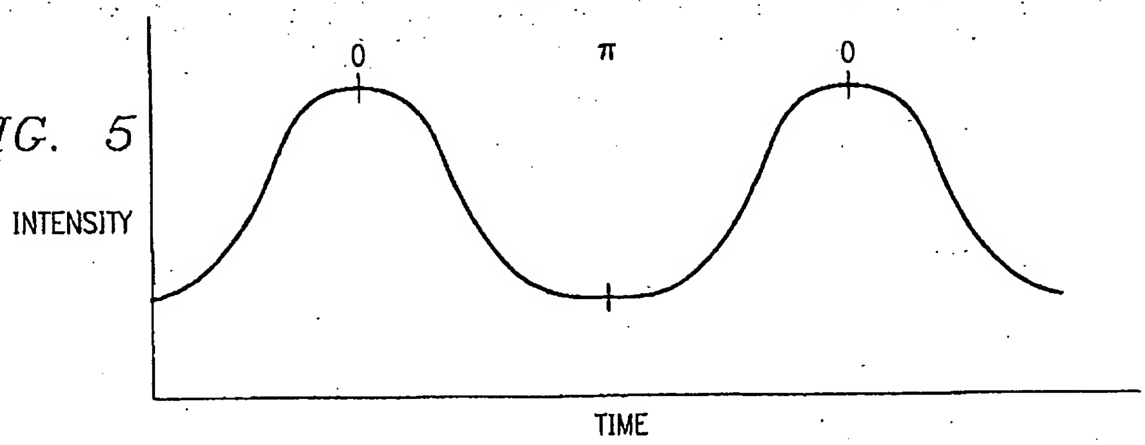


FIG. 6

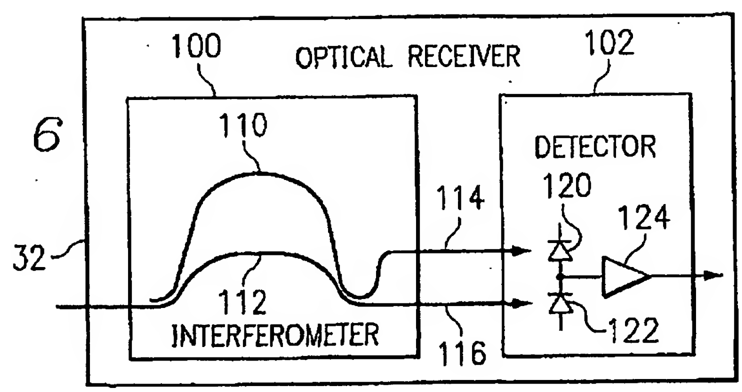
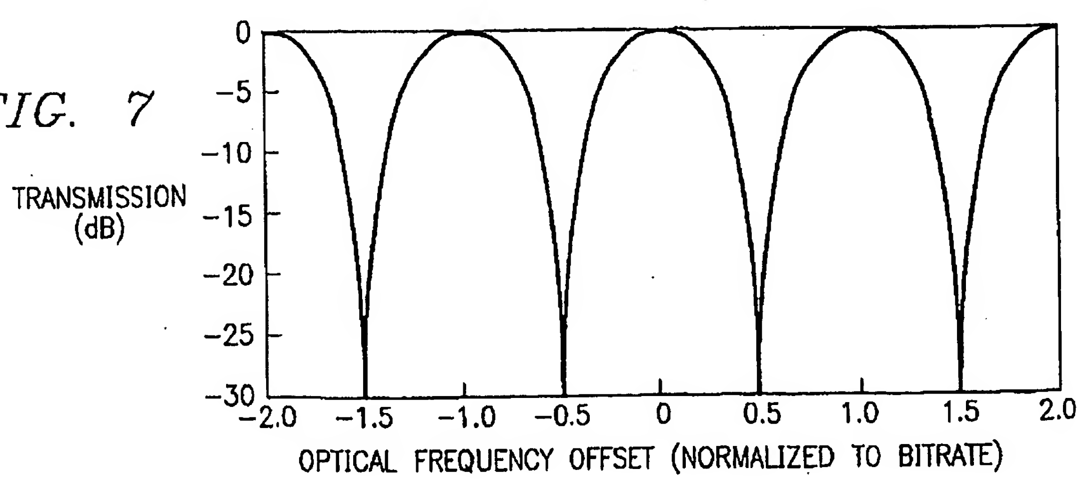


FIG. 7



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